U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 203.

B. T. GALLOWAY, *Chief of Bureau.*

THE IMPORTANCE AND IMPROVEMENT OF THE GRAIN SORGHUMS.

BY

CARLETON R. BALL,

Agronomist in Charge of Grain-Sorghum Investigations.

Issued January 20, 1911.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1911.

BUREAU OF PLANT INDUSTRY.

Chief of Bureau, BEVERLY T. GALLOWAY.
Assistant Chief of Bureau, WILLIAM A. TAYLOR.
Editor, J. E. ROCKWELL.
Chief Clerk, JAMES E. JONES.

GRAIN INVESTIGATIONS.

SCIENTIFIC STAFF.

Mark Alfred Carleton, *Cerealist in Charge.*

C. R. Ball, C. W. Warburton, and H. B. Derr, *Agronomists.*
Charles E. Chambliss, *Expert.*
Edward C. Johnson, *Pathologist.*
H. J. C. Umberger and H. F. Blanchard, *Assistant Agronomists.*
Cecil Salmon, *Physiologist.*
John F. Ross, *Farm Superintendent.*
A. A. Potter, *Assistant Pathologist.*
Manley Champlin, V. L. Cory, H. V. Harlan, and W. G. Shelley, *Scientific Assistants.*
F. R. Babcock, *Assistant.*
E. L. Adams, L. C. Burnett, P. V. Cardon, S. D. Gray, and J. M. Jenkins, *Agents.*

203

2

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., September 21, 1910.

Sir: I have the honor to transmit herewith a paper entitled "The Importance and Improvement of the Grain Sorghums," by Mr. Carleton R. Ball, Agronomist in Charge of Grain-Sorghum Investigations, and recommend its publication as Bulletin No. 203 of the series of this Bureau. This paper presents the best known methods of improving these crops, both at experimental stations and on the farms where they are grown. The value of the grain for feeding stock and poultry is shown, and the acreage, yields, and acre values of these crops are recorded so far as data are available. The facts presented are the result of four years of work in the Office of Grain Investigations.

The areas devoted to grain sorghums in the dry regions of the Southwest are rapidly increasing. Their earliness, productive power, and strong drought resistance especially adapt them to semiarid conditions. The importance of these crops, however, is even greater than can be measured in terms of increased acreage. They are not only staple crops, but in many places they are the chief dependence of the new settler, and their success or failure determines his ability to become established.

Respectfully,

Wm. A. Taylor,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS

ILLUSTRATIONS.

B. P. I—620.

THE IMPORTANCE AND IMPROVEMENT OF THE GRAIN SORGHUMS.

INTRODUCTION.

The aim of this paper is to show the importance and uses of the grain sorghums and to indicate how they may be further improved. By grain sorghums are meant all the different varieties of the milo, durra, kafir, and kowliang groups of sorghums. These groups are grown primarily for the grain they produce; only the kafirs are grown to any great extent for forage apart from the grain. By improvement is meant changes in methods of handling and in the habits of the plants themselves. These changes must be such as will make them better yielders or otherwise better adapted to the needs of the grower.

In many localities unimproved varieties of grain sorghums are being grown. Most farmers can improve their local varieties. Some of them do so to a very creditable extent, others neglect this entirely. Such work should be much more generally done, and probably would be if the methods of doing it were more commonly understood. In some communities improved varieties have been introduced and are grown by most of the farmers. The work of improving these must be continued by the growers, however, or they are likely to become gradually poorer. This deterioration is caused by mixing with unimproved strains of the same variety or through crossing with other varieties.

Such crossing, or hybridizing, is more common in the sorghums than in most other farm crops. This is because they are all open fertilized; that is, intended to be cross fertilized by means of the wind. The ease with which such crossing occurs is increased because they are most largely grown in regions of fairly constant winds and because their greater height enables the wind to carry the pollen of sorghums farther than that of lower crops.

Before taking up the study of methods of improvement it is desirable to consider the region in which the grain sorghums are grown and to know something of the origin, history, general adaptations, and importance of the crops themselves.

THE GRAIN-SORGHUM BELT.

BOUNDARIES.

The grain sorghums are most largely grown in the southern half of the Great Plains region (fig. 1).

Broadly speaking, this region includes the plain lying between the ninety-eighth meridian of longitude and the Rocky Mountains. The

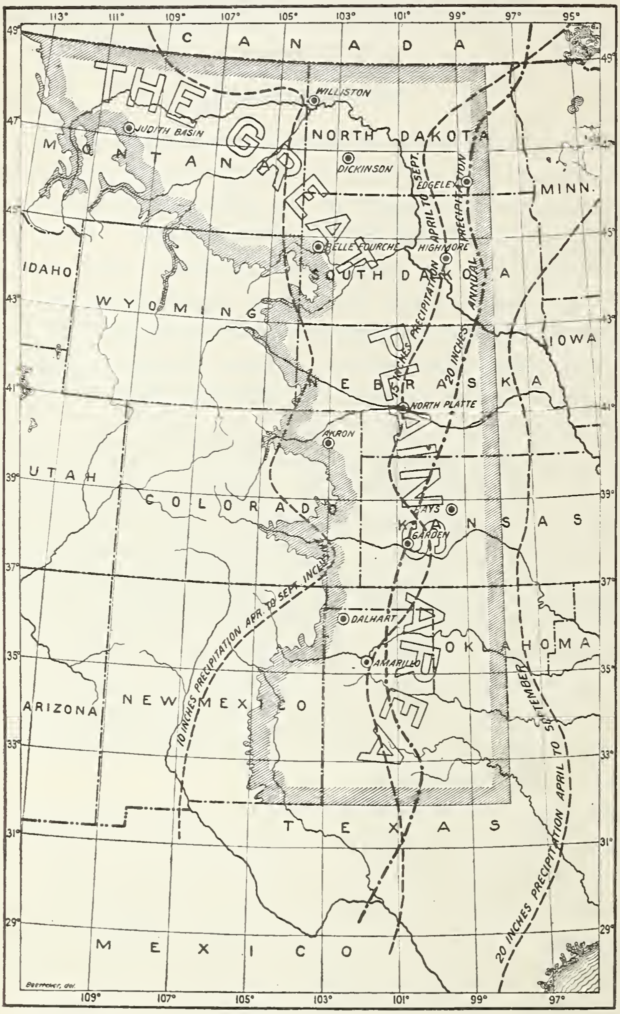

FIG. 1.—Map of the Great Plains area, showing the annual and the seasonal rainfall.

southern half of it may be said to include the area between the northern boundary of Kansas and the Mexican border, although the extreme southern part of western Texas does not belong to the Great Plains proper. The area thus bounded takes in the western half of

Kansas, the western third of Oklahoma, the western half of Texas, and all those portions of Colorado and New Mexico that lie east of the Rocky Mountains. In round numbers the area is 400 miles wide and 1,000 miles long. So important are these crops in this area that it may well be called the "grain-sorghum belt."

SURFACE FEATURES.

The surface of the area just outlined is in general a gently rolling plain, sloping steadily eastward from an elevation of 4,000 to 5,000 feet at the base of the Rocky Mountains to an average elevation of 1,000 to 1,500 feet at the ninety-eighth meridian. The highest point in these plains is not at the base of the mountains, but some distance east of them, in Elbert and El Paso counties, Colorado, where the altitude increases to nearly or quite 6,500 feet. While the main slope is toward the east, there is also a secondary slope to the north and south from this high area in Colorado. Looked at from above the surface of the whole Great Plains region may be compared in outline to half of an inverted saucer, the rim lying toward the east.

SOILS AND PLANT COVERING.

The soils of this region vary from the dark clays of the central Panhandle and the red clays of western Oklahoma, through sandy loams found in various parts of the region to very sandy soils, such as characterize the sand-hill country of Kansas and Colorado.

The plant covering of the loams and clays is mostly a dense sod of buffalo grass and blue grama mixed. In southwest Texas the buffalo grass gives place to the curly mesquite, or running mesquite, as it is often called (*Hilaria cenchroides*). On the more sandy soils taller and more bunchy grasses prevail, such as the bluestems (*Andropogon provincialis*, *A. scoparius*, *A. saccharoides*, etc.). In much of western Texas the plains have been largely covered by a more or less dense growth of the mesquite tree (Prosopis). In southern Texas this becomes a large tree, but as it ascends to the higher plains its size diminishes until in the upper Panhandle it is only a low shrub or bush.

CLIMATE.

What really separates the so-called Great Plains region from the country lying immediately east of it is, primarily, not differences in either elevation or soil, but the lower rainfall and higher evaporation of moisture. The average annual rainfall for the grain-sorghum belt, as defined above, is about 20 inches, of which more than half comes in the months of April to September, inclusive. (See fig. 1.) The summer temperature is fairly high, and this, with the steady breeze which prevails over much of this area, makes evaporation rapid and continuous.

All crops to be suitable for use in this area must have the ability either to withstand or to escape drought in one way or another. Dry, hot winds occasionally occur in some parts of the region, often quickly and completely destroying all tender vegetation. At the higher elevations and in the northern part generally the season is comparatively short and early varieties must be used, because late spring frosts occur and the first frosts of autumn come rather early.

AGRICULTURAL DEVELOPMENT.

The process of dividing the great cattle ranges and selling them for farms is going on steadily. Wherever government land remains homesteads are being taken up. In the past few years the settlement of this dry country has been rapid. Rapid settlement may be desirable; it is much more important, however, that it be permanent. This has not always been the case.

No one may say with certainty just what the future of this southern Great Plains region is to be. It gives promise of becoming a second great feeding belt, similar to the corn belt. Nothing better could be wished than that it should grow live stock and the crops to feed them. Under such a system of farming this area would produce much more live stock than it ever did or could under the ranch and range system. If it should raise a money crop in addition, so much the better. This might be cotton in the southern part, winter wheat in the central, and spring wheat in the northern part, with broom corn and other minor crops in different parts. The area is admirably adapted to the growing of both the stock and the necessary feeding crops. These crops will be corn in the regions of lower altitude and greater rainfall and grain sorghums in the higher and drier parts.

IMPORTANCE OF THE GRAIN-SORGHUM CROP.

The following paragraphs cover briefly the history of the grain sorghums in the United States, the general conditions to which they are adapted, and some statistics of their acreage, yield, and value.

HISTORY OF THE VARIETIES.

It is only thirty-five years since the first grain sorghums (fig. 2) were introduced into the United States. It is only twenty years since any of them have become crops of recognized importance. Although grain-producing varieties had probably been introduced from time to time since early colonial days none had persisted in cultivation.

The first permanent introductions were the two durras, Brown durra and White durra, which reached California in 1874 under the

names, "Brown Egyptian corn" and "White Egyptian corn." The white variety had two periods of popularity in the Great Plains area, first, in the early eighties, under the name "Rice corn," and again, ten years later, under the name "Jerusalem corn." Both varieties are still grown, but only to a limited extent owing to their shattering habit.

Two varieties of kafir, the White and the Red, were brought from South Africa in 1876. They did not get into general cultivation here until about 1890, fourteen years later. The Blackhull kafir appeared

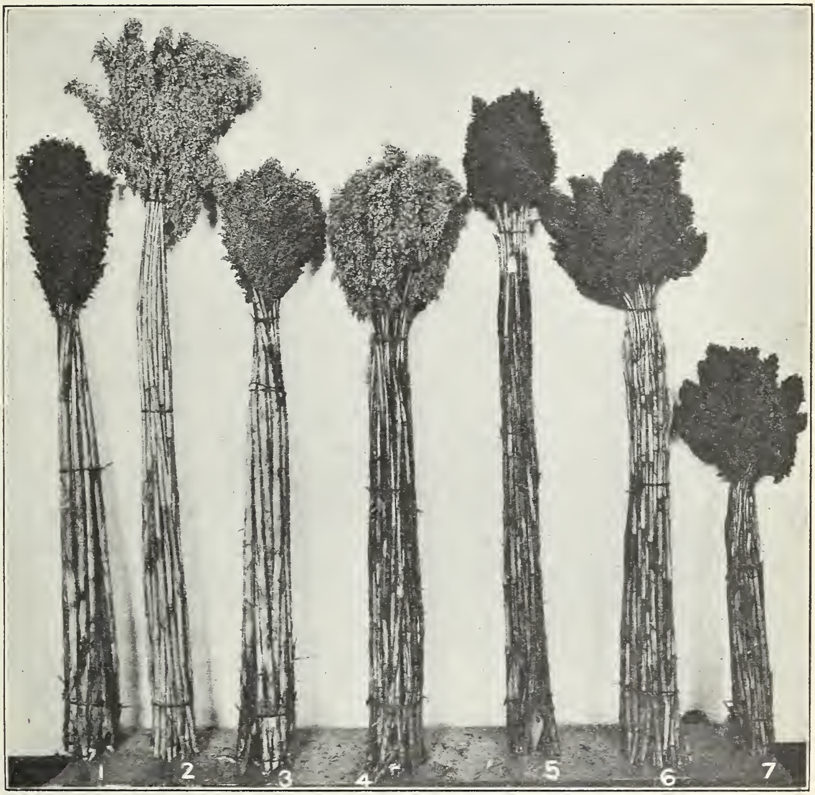

FIG. 2.—Sheaves of improved grain sorghums: 1, Red kafir; 2, shallu; 3, Blackhull kafir; 4, White durra; 5, Brown kowliang; 6, milo; 7, Dwarf milo.

soon after, but whether it was a part of the original importation or was a later introduction will probably never be known. The original White kafir is rarely found in cultivation to-day, but the Red and the Blackhull are important crops.

Milo was first introduced into South Carolina or Georgia about the year 1885, but did not come into general notice until about 1890, when it had become a staple crop in parts of western Texas.

The kowliangs have been coming from China and Manchuria since 1901. Most of them have required considerable selection to make them suitable for use as grain crops. None of them has been long enough in the hands of farmers to be considered a farm crop.

In the brief space of twenty years, however, the milos and kafirs have greatly increased in importance. They are now grown as staple farm crops on a large scale over a considerable area of the West.

ADAPTATIONS TO THE GRAIN-SORGHUM BELT.

It is in the western region previously described that the grain sorghums prove themselves most completely at home. They are here not only staple crops, but they are often the chief dependence of the new settler, because they may be grown as sod crops. By homesteaders with small means and limited equipment, they can be cheaply planted on breaking. They are often planted, cultivated, harvested, and even thrashed by hand under such circumstances.

When these crops were first introduced they were tried in various parts of the United States. One after another they were found unsuited to the conditions in most of the country and were discarded. But out on the Great Plains they grew in favor with the farmer because they were able to stand the prevailing conditions. They are able to grow and make profitable yields in hotter, drier climates than most crops. Some of them are early enough for use at comparatively high elevations. They are all cultivated crops, entering readily into the rotation with small grains. They furnish the feeding grain required on the farm, also some roughness, and occasionally both fuel and food in addition. The surplus can always be sold at fair to good prices. When grown on a large scale they are handled rapidly and profitably by machinery in every necessary operation from seeding to milling. They are undoubtedly suited to become the basis of a cattle-feeding industry that will make the Great Plains farmer prosperous.

USES OF THE GRAIN.

STOCK FEED.

Primarily these grains are and ought to be useful in feeding stock on the farms where they are grown. This fact accords with the history of these crops and is due to their adaptations for such use. They were the principal crops of the early settler in the dry-land areas of the southern Great Plains region. He not only needed a feeding grain but was often too far from market to sell it profitably if he had wished.

The value of the grain for keeping work stock, growing animals, and dairy cows in excellent condition has long been recognized among the growers. The knowledge of its value in fattening cattle and hogs for

market is increasing. A number of experiments to determine the feeding value have been conducted at the agricultural experiment stations of Kansas,[a] Oklahoma,[b] and Texas.[c] In many of these trials the Blackhull-kafir grain, which was most generally used, was shown to have a feeding value little below that of corn.

Table I shows the average chemical composition of a large number of samples of grain sorghums. In order to show the range of variation in composition, the minimum and maximum percentages found are given also. The analyses of the grain sorghums were made by Dr. J. S. Chamberlain, of the Bureau of Chemistry, in cooperation with the Office of Grain Investigations of the Bureau of Plant Industry. For comparison, the minimum, maximum, and average percentages found in 208 analyses of corn kernels are reprinted from Bulletin 11 of the Office of Experiment Stations.

The average analyses of all the grain-sorghum samples and all the corn samples are fairly comparable. The 49 grain-sorghum samples were grown in 1905, 1906, and 1907, mostly in the Great Plains area. The 208 corn samples were grown in many different States and years. The average composition of 10 grain-sorghum samples and of 12 corn samples grown at different times and places, determined by Doctor Chamberlain, and reprinted from Bulletin 120 of the Bureau of Chemistry, is also included in the table. From these figures and from others based on fewer analyses, but covering both crops grown under similar conditions, it is known that they are not very different in composition. In general, the grain-sorghum kernels average a little higher than corn in protein content and a little lower in ether extract, or fat, and in fiber. The range of variation in the protein content, from 7.93 to 16.63 per cent, indicates that high-protein varieties and strains can probably be readily developed by selecting for this quality.

---

[a] Bulletin 56, Kansas Agricultural Experiment Station.

[b] Bulletins 35, 37, and 46, Oklahoma Agricultural Experiment Station.

[c] Bulletins 95, 97, 104, and 110, Texas Agricultural Experiment Station; also an unnumbered circular of the Texas Agricultural Experiment Station entitled "Panhandle Feeds for Beef Production."

TABLE I.—*Composition of grain-sorghum kernels and corn kernels.*

Crop and percentage.	Number of analyses.	Water.	Water-free substance.				
			Ash.	Crude protein (N×6.25).	Fiber.	Carbohydrates.	Ether extract.
Milo:							
Minimum		9.82	1.57	10.34	1.73	78.91	2.80
Maximum		11.08	1.95	14.34	2.11	82.67	3.31
Average	8	10.61	1.77	12.41	1.86	80.87	3.09
Dwarf milo:							
Minimum		10.18	1.80	11.35	1.68	79.75	2.89
Maximum		10.52	2.06	12.84	2.66	81.92	3.51
Average	4	10.34	1.93	12.08	2.02	80.73	3.24
White durra:							
Minimum		9.70	1.93	7.93	1.49	78.33	3.34
Maximum		10.16	2.43	12.39	2.32	84.90	4.31
Average	5	9.87	2.17	11.22	1.85	80.81	3.95
Blackhull kafir:							
Minimum		9.87	1.80	9.93	1.84	76.88	3.08
Maximum		10.16	1.97	15.64	2.39	82.12	3.79
Average	5	10.05	1.90	13.69	2.08	78.87	3.46
Red kafir:							
Minimum		10.16	1.60	12.04	1.68	78.11	2.46
Maximum		10.55	2.05	14.47	2.91	81.26	3.48
Average	3	10.31	1.78	13.01	2.14	79.95	3.12
Brown kowliang:							
Minimum		9.75	1.76	8.80	1.46	79.13	4.37
Maximum		10.86	2.26	12.13	2.59	82.83	4.95
Average	7	10.26	2.12	10.51	1.75	80.98	4.64
Blackhull kowliang	1	9.99	1.96	11.52	1.63	80.18	4.71
White kowliang	1	10.05	2.40	11.53	1.39	79.53	5.15
Shallu:							
Minimum		9.37	1.42	13.01	1.73	76.42	2.57
Maximum		10.06	2.12	15.24	1.96	80.87	4.33
Average	3	9.70	1.76	13.88	1.85	78.78	3.72
Grain sorghums:							
Minimum		9.37	1.36	7.93	1.39	76.42	2.46
Maximum		11.08	2.43	16.63	2.91	84.90	5.15
Average	49	10.22	1.93	12.23	1.92	80.06	3.86
Average of other samples[a]	10	11.71	1.75	11.71	1.80	81.58	3.25
Corn grown in many States and different years:							
Minimum		4.50	1.10	7.70	.80	67.20	3.80
Maximum		20.70	3.10	17.00	5.70	84.80	12.80
Average	[b] 208	10.89	1.70	11.70	2.40	78.10	6.10
Average of other samples[a]	12	13.06	1.52	9.91	2.21	81.96	4.40

[a] Chamberlain, J. S. The Feeding Value of Cereals, as Calculated from Chemical Analyses, Bulletin 120, Bureau of Chemistry, U. S. Dept. of Agriculture, 1909, p. 42.
[b] Jenkins, E. H., and Winton, A. L. A Compilation of Analyses of American Feeding Stuffs, Bulletin 11, Office of Experiment Stations, U. S. Dept. of Agriculture, 1892, pp. 16–17.

Table II gives some analyses, on the air-dry basis, made by the Texas Agricultural Experiment Station and published in Bulletin 95 of that station. Chops are composed of thrashed grain, more or less finely chopped or crushed. Head chops are made by chopping the unthrashed heads, and are therefore similar to and comparable with the corn-and-cob meal. The high fiber content of these last-named products is due, of course, to the woody panicle branches and cobs. The fiber content of thrashed seed, free from the glumes, seldom runs higher than 2 or 2.5 per cent.

TABLE II.—*Composition of chops, head chops, and corn-and-cob meal.*

Crop and product.	Number of analyses.	Air-dry substance.					
		Water.	Ash.	Crude protein (N×6.25).	Fiber.	Carbohy-drates.	Ether extract.
Milo chops	14	9.66	2.30	10.73	3.05	72.22	2.78
Kafir chops	19	9.86	1.63	10.98	2.75	71.18	3.12
Corn chops	9	11.81	1.19	9.60	2.52	71.71	3.90
	475	....	....	9.30	....	....	4.10
Milo head chops	4	9.42	2.71	9.22	6.51	69.55	2.44
Kafir head chops	3	13.62	2.82	9.25	8.03	63.38	2.62
Corn-and-cob meal	10	10.01	1.28	10.14	7.10	68.78	3.69
	10	....	2.01	8.51	7.98	....	3.49

Many grain elevators in the Great Plains region have been equipped with machinery for thrashing and grinding these grains. The grain should be cracked or ground before feeding to get the best results. In the form of milo chops and kafir chops, it is becoming a popular

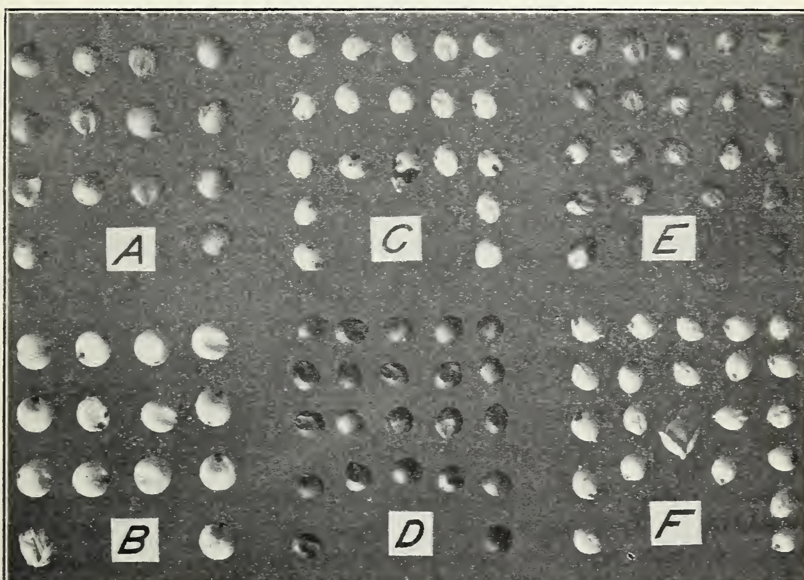

FIG. 3.—Seeds of grain sorghums: *A*, Milo; *B*, White durra; *C*, Blackhull kafir; *D*, Red kafir; *E*, Brown kowliang; *F*, shallu. (Natural size.)

commercial article. Head chops are not meeting with as much favor because of the included "dirt," composed of the glumes, glume hairs, awns, etc. It is for this reason that the elevators have installed thrashing machinery.

POULTRY FEED.

The grain-sorghum seeds (fig. 3) are splendidly adapted, both in size and composition, for feeding to all classes of poultry. In many parts

of the country, outside the grain-sorghum belt, small patches of kafir, durra, or other "chicken corn" are commonly grown on the farm simply to furnish chicken feed.

In 1908 inquiries were addressed to 114 firms manufacturing over 200 brands of poultry food. Data received from 33 firms show an annual output of about 30,000 tons of these products. Of this total quantity about 10,000 tons, or one-third of the total, consisted of Blackhull kafir seed. This was mostly used in mixtures with other grains, as corn, wheat, etc. From these facts it is probably safe to conclude that kafir or other grain-sorghum seed forms at least 25 per cent of the prepared poultry food sold in this country. So strong is the demand for these grains by poultry-food manufacturers that similar varieties have been imported from as far away as India when the crop in this country was short. Such importations are being made at the date of writing.

HUMAN FOOD.

Meal made from the grain sorghums ground locally is not infrequently used in the making of batter cakes and similar articles of food on the farm. The general testimony is that these are delicious in quality. Some experiments are now being conducted in a small way to determine the value of the meal for more extended use. There seems little reason why, when properly milled, it should not be used in much the same manner as corn meal. Throughout Africa, India, and the other parts of southern and eastern Asia, where these crops are largely grown, they are not only commonly used as human food, but in many countries they furnish the chief article of diet.

STATISTICS OF ACREAGE, YIELD, AND VALUE.

SCOPE OF DATA.

Complete statistics of the production of grain-sorghum crops are not available. The national census, taken every ten years, has not yet separated them in its schedules from other related crops. Of the five or six States which grow them largely, only two—Kansas and Oklahoma—gather state statistics of farm crops. The figures have been gathered in Kansas since 1893, but in Oklahoma only since 1904 for kafir and since 1905 for milo.

TOTAL GRAIN-SORGHUM CROPS IN KANSAS AND OKLAHOMA.

Table III shows the acreage, yield, and value of grain sorghums grown in Kansas and Oklahoma for a series of years. These results have been compiled and adapted from the figures given in the reports of the State Board of Agriculture for each of the two States.

In the Kansas figures three groups of grain sorghums are included, namely, kafirs, milos, and White durra ("Jerusalem corn"). Since

the area devoted to the White durra has not been larger than 4,000 acres but once in the last fifteen years, it may be neglected and the figures regarded as representing only kafirs and milos—the two staple crops. The yield for Kansas is shown in tons of fodder per acre, instead of bushels of grain.

In the figures for Oklahoma two groups of grain sorghums are included, namely, kafirs and milos, except for the first year, 1904, in which no returns were obtained for milo, and the figures given are for kafir only. For the years 1904 to 1906, inclusive, the returns are from only the former Territory of Oklahoma. For 1907 and 1908 they are from the entire new State, including the former Indian Territory. This probably accounts for the apparent sudden increase in acreage of 1907 over 1906.

The yield for Oklahoma is shown in bushels of grain per acre. The value of the crops is computed from the value of the grain alone for all the years except 1908. In that year returns were also made for the tonnage and value of the stalks. The value of the stalks has therefore been added to the value of the grain for that year to make the total value of the crops, from which the acre value is computed. The value of kafir stalks was found to be nearly one-half as much as the value of the kafir grain, or nearly one-third the combined value of both. The stalk value of milo was exactly one-fourth the grain value, or one-fifth of the combined value. It is not clear from the Oklahoma reports whether the fodder and grain represent the product of the same fields or whether the figures for fodder are intended to cover fields not used for grain. It is here assumed that the former was intended.

TABLE III.—*Acreage, yield, and value of total grain-sorghum crops for certain years in Kansas and Oklahoma.*

Year.	Kansas.					Oklahoma.				
	Acreage.	Yield in tons.		Value.		Acreage.	Yield in bushels.		Value.	
		Total.	Per acre.	Total.	Per acre.		Total.	Per acre.	Total.	Per acre.
1893	77,942	190,489	2.44	$553,320	$7.10					
1895	231,498	793,154	3.43	2,079,285	8.98					
1900	652,667	1,985,940	3.04	5,814,389	8.91					
1904	528,142	1,609,038	3.05	5,136,412	9.72	334,948	3,280,510	9.79	$1,312,204	$3.92
1905	575,038	1,862,799	3.24	5,726,978	9.96	435,894	6,562,298	15.05	2,624,920	6.01
1906	569,701	1,727,965	3.03	5,216,985	9.16	391,565	6,513,926	16.63	2,336,704	5.97
1907	533,007	1,561,943	2.93	5,919,197	11.10	502,771	6,757,197	13.44	4,023,130	8.00
1908	688,582	1,908,551	2.77	7,407,516	10.76	545,143	5,529,219	10.14	3,305,765	6.06
1909	741,983	1,987,258	2.67	8,145,508	10.98					
Average for years since 1904, inclusive			2.95		10.28			13.01		5.99

It will be noted that the total area devoted to grain-sorghum crops in Kansas was larger in 1900 than in 1905. The maximum acreage was reached in 1902, with a total of 757,000 acres. After 1902, the acreage decreased slowly until 1907, and then began a steady increase. It may be noted that in 1907, the year of lowest acreage, the highest value per acre resulted. In Oklahoma there has been a fairly constant increase in acreage during the years covered by the statistics. In both States there has been a general rise in the acre value of these crops. The figures do not indicate, however, that yields per acre are increasing.

KAFIR, MILO, AND CORN CROPS IN KANSAS AND OKLAHOMA.

Table IV shows the annual production of kafir, milo, and corn in Kansas and Oklahoma for the years since 1904, inclusive.

The proportion of grain sorghums to corn grown in these States is steadily increasing with the settlement of the drier western portions. The average acreage of grain sorghums for the period 1904 to 1909 in Kansas was equal to 8.7 per cent of the average corn acreage. For the year 1909 alone it had increased to 9.6 per cent in spite of an enormous increase in the corn acreage. In Oklahoma the same figures are not comparable because of the change from a small Territory to a larger State, but the average grain-sorghum acreage in the old Territory from 1904 to 1906 was equal to 25.6 per cent of the corn area. In 1907, in the new State, including both Oklahoma and Indian Territories, it was 12.5 per cent, and in 1908 12.7 per cent. The apparent decrease in the second period is due to the fact that Indian Territory grew much corn and little grain sorghum.

As pointed out before, the grain sorghums are all grown most extensively in the drier areas west of the ninety-eighth meridian. In Kansas about 45 per cent of the kafir and about 95 per cent of the milo is found west of this line, which divides the State almost exactly in half. In Oklahoma about one-third of the State lies west of this line and contains 79 per cent of the kafir and 98 per cent of the milo.

TABLE IV.—*Acreage, value, and yield of kafir, milo, and corn for the years 1904 to 1909, inclusive, in Kansas and Oklahoma.*

Crop and year.	Kansas.					Oklahoma.				
	Acreage.	Yield per acre in tons or bushels.	Value.			Acreage.	Yield per acre.	Value.		
			Per ton or bushel.	Total.	Per acre.			Per bushel.	Total.	Per acre.
Kafir:		*Tons.*	*Per ton.*				*Bush.*			
1904	518,372	3.04	$3.19	$5,041,546	$9.70	334,948	9.79	$0.40	$1,312,204	$3.92
1905	538,393	3.24	3.06	5,352,810	9.91	297,286	12.72	.40	1,512,318	5.08
1906	548,497	3.05	3.01	5,039,238	9.18	269,218	16.10	.34	1,465,937	5.44
1907	508,485	2.94	3.78	5,658,860	11.11	371,405	13.50	.58	2,881,032	7.77
1908	630,096	2.85	3.82	6,856,845	10.89	400,047	9.20	.46	[a]2,548,200	6.36
1909	636,201	2.79	4.02	7,150,080	11.21					
Average		2.99	3.48		10.33		12.26	.44		5.71
Milo:										
1904	7,166	3.18	3.22	73,476	10.24					
1905	20,550	2.84	3.28	190,974	9.31	138,608	20.06	.40	1,112,602	8.02
1906	17,563	2.55	3.26	146,289	8.31	122,347	17.82	.40	870,767	7.12
1907	22,090	2.72	3.90	234,686	10.61	131,366	13.30	.65	1,142,098	8.64
1908	55,255	1.92	4.85	515,269	9.31	145,096	12.55	.33	[b]757,565	5.22
1909	102,492	1.97	4.74	959,259	9.34					
Average		2.53	3.87		9.52		15.93	.45		7.25
Corn:		*Bushels.*	*Per bushel.*							
1904	6,494,158	20.3	.39	50,713,955	7.81	1,369,276	16.00	.39	8,544,339	6.24
1905	6,799,755	28.0	.36	68,718,584	10.11	1,642,930	18.90	.40	12,436,557	7.56
1906	6,584,535	28.4	.35	65,115,203	9.25	1,528,735	31.40	.36	17,142,081	11.21
1907	6,809,012	21.3	.43	63,040,743	9.26	4,014,631	18.10	.48	35,409,961	8.82
1908	7,057,535	21.3	.55	82,642,462	11.71	4,284,561	18.60	.48	38,449,866	8.97
1909	7,711,879	19.1	.57	83,066,905	10.77					
Average		23.1	.44		9.83		20.60	.42		8.56

[a] Includes $828,131 worth of fodder. [b] Includes $151,911 worth of fodder.

The 46 counties in the western half of Kansas grew, in round numbers, 240,000 acres of grain sorghums in 1907, 334,000 acres in 1908, and 396,000 acres in 1909. This was an increase of 39 per cent in the grain-sorghum acreage for 1908 and of 18.6 per cent for 1909. The same counties grew 1,500,000 acres of corn in 1907, 1,750,000 acres in 1908, and 2,000,000 acres in 1909, increases of 17 and 14 per cent, respectively. The ratio of the acreage of grain sorghums to that of corn was 1 to 6.2 in 1907, 1 to 5.3 in 1908, and 1 to 5.1 in 1909. The grain-sorghum acreage was therefore equal to 16.1 per cent, 18.9 per cent, and 19.5 per cent of the corn acreage of these three years, respectively. Ten of these counties grow larger areas of grain sorghum than of corn.

The 21 counties now comprising the western third of Oklahoma grew 327,000 acres of grain sorghum in 1906, 423,000 acres in 1907 (29 per cent increase), and 465,000 acres in 1908 (10 per cent increase). The ratio of grain-sorghum acreage to that of corn was 1 to 2.1 in 1906, 1 to 2.7 in 1907, and 1 to 3.1 in 1908. These ratios represent grain-sorghum acreages equal to 47.6 per cent, 37 per cent, and 32.2

per cent of the corn acreages for the same years. Four of these counties grow more grain sorghums than corn.

SUMMARY OF THE VALUES OF GRAIN SORGHUM AND CORN IN KANSAS AND OKLAHOMA.

In Table V is given the minimum, maximum, and average value per acre of grain-sorghum and corn crops in Kansas and Oklahoma. The figures are a summary of the values given in Tables III and IV. It will be noted that for Kansas the minimum acre value of the combined grain sorghums is not as low as the minimum for corn, that the maximum is nearly as high, and that the average acre value is higher by 45 cents an acre. In Oklahoma the relative positions of the crops are reversed.

Two facts must be kept in mind while comparing these figures. One is that for Kansas the yields and values of grain sorghums are based on tons per acre, and thus include the value of both grain and stover. The yields and values of corn, on the contrary, are based on bushels of grain per acre. If the value of the corn stover were also included, the average acre value for corn would probably somewhat exceed that of the grain sorghums. The difference, however, would probably not be as large as the Oklahoma figures show. The other fact is that the grain sorghums are most largely grown in the western parts of these States. Here the shorter seasons and lower rainfall tend to decrease the yields of all crops. This puts the sorghums at a disadvantage in a comparison with corn, which is most extensively grown in the lower and more humid portions.

TABLE V.—*Summary of values of grain sorghums and corn in Kansas and Oklahoma.*

State and crop.	Number of years.	Yield per acre.	Price per ton or bushel.	Acre value.				
				Minimum.		Maximum.		Average.
				Year.	Value.	Year.	Value.	
Kansas:		*Tons.*	*Per ton.*					
Kafir	6	2.99	$3.48	1906	$9.18	1909	$11.21	$10.33
Milo	6	2.53	3.87	1906	8.31	1907	10.61	9.52
Total grain sorghums	6	2.95	3.48	1906	9.16	1907	11.10	10.28
		Bushels.	*Per bu.*					
Corn	6	33.10	0.44	1904	7.81	1908	11.71	9.83
Oklahoma:								
Kafir	5	12.26	.44	1904	3.92	1907	7.77	5.71
Milo	4	15.93	.45	1908	5.22	1907	8.64	7.25
Total grain sorghums	5	13.01	.44	1904	3.92	1907	8.00	5.99
Corn	5	20.60	.42	1904	6.24	1906	11.21	8.56

IMPROVING THE GRAIN SORGHUMS.

There are two general ways by which grain-sorghum crops can be made of greater value to the grower. First, by improving the varieties; second, by devising more rapid and economical methods of har-

vesting. Improved varieties can be secured through selection of present sorts (fig. 4), and by bettering the methods of planting them. More rapid and economical harvesting will come about either through adapting the crops to present machinery or through the invention of new machines, or both.

It is better to keep in view the results sought rather than the means by which these results are to be attained. The problems of improvement will therefore be discussed under headings showing the most

FIG. 4.—Plat of milo, selected for erect heads and low stature.

important results desired. These problems are five in number, namely, (1) increased drought resistance, (2) increased earliness, (3) dwarfness (or diminished stature), (4) greater productiveness, and (5) adaptability to machine handling.

DROUGHT RESISTANCE.

The grain sorghums find their greatest usefulness in regions where moisture is often the controlling factor in crop production. Much

good should therefore be accomplished by increasing their drought resistance, especially in the areas of lighter rainfall.

No one knows exactly what drought resistance is. It is probable that the character called drought resistance is one of several different factors or the result of a combination of two or more of them. The most important of these factors are probably (1) increased ability to prevent the loss of water by transpiration, (2) increased development of the root system, and (3) a possible increase in power to extract water from a dry soil.

Differences in the power to control transpiration are well-known and readily observed facts. In cacti, for instance, this ability is highly perfected. Corn is in danger when the leaves begin to curl, but sorghums often remain in this condition for a long time without permanent injury.

The size and character of the root system are probably a strong factor in drought resistance. The larger the root system in proportion to the plant, the better it can supply moisture. The wider and deeper its penetration, the larger the area of soil from which it draws moisture in time of drought. A deeply rooting plant may be able to secure water when shallow root systems lie wholly in dry soil. This is entirely apart from possible differences in ability to extract moisture from a given unit of soil. Such differences may exist, but the idea is yet only a theory. Unfortunately, the character of the root system can not be observed while making selections.

Selections for drought resistance will usually be made on observed phenomena. These are likely to be the result of a combination of adaptations for actual drought resistance and adaptations for drought evasion. Dwarfness, earliness, and thin stands are adaptations or conditions for drought evasion. Making allowance for these when present, one can select for actual drought resistance. This will be done by using those plants which give best results under dry conditions when they are neither dwarfer, nor earlier, nor more thinly planted than their neighbors.

EARLINESS.

ADVANTAGES TO BE GAINED.

The two principal reasons for desiring early varieties are, first, to extend the range of grain sorghums into dry regions having a short growing season; and, second, to obtain the fullest possible benefit from the seasonal rainfall, which comes largely during the early summer months in parts of the grain-sorghum belt. This second reason is thus connected with the problem of drought resistance, though, as pointed out, earliness is a means of drought evasion, not of resistance.

Improvement in earliness will need to be continued for a long time if varieties are to be perfected for the needs of all the dry-farming regions.

EARLY VARIETIES.

The milos (figs. 4 and 8) are much earlier varieties than the kafirs, and are very promising material on which to work. In the Panhandle of Texas, at elevations of 3,000 to 4,000 feet, they now mature in ninety to one hundred days when sown May 15 to 20. At present they are grown successfully at altitudes between 4,000 and 5,000 feet in Texas, New Mexico, and Colorado. At higher elevations the growing season is shortened to such an extent that the present

FIG. 5.—Plat of White durra with 100 per cent of the heads erect.

varieties of milo do not mature. At lower elevations their present range extends northward into southwestern Nebraska. In northern Nebraska, the Dakotas, Montana, and Idaho the increasing latitude and shorter growing season prevent their successful maturing. It seems certain, also, that the soil, especially at night, is too cool to permit vigorous growth, thus retarding the maturing of the plant even where the season is otherwise long enough.

The durra group contains some very early varieties. The only one well known in this country is the common White durra (fig. 5), which has been called "White Egyptian corn," "Rice corn," and "Jerusalem corn," in the successive periods of its popularity. It matures as early as or slightly earlier than the milos. White durra

apparently possesses true drought resistance also, and is productive, but shatters quite badly and is not liked for that reason and some minor ones. Some hybrids of this variety with Blackhull kafir have been under selection for three years and give promise of being valuable.

The kafirs usually require about three weeks longer than milo to mature under the same conditions. An early strain of Blackhull kafir (fig. 6) developed by the writer, through selection, matures about two weeks earlier than the ordinary kafirs and only three to

FIG. 6.—Plat of dwarf and early Blackhull kafir (G. I. No. 340).

five days later than milo. The old-fashioned White kafir, with white hulls, now rarely found in cultivation, was a semi-early sort and would make good selection stock if its heads were free from the boot and if it were not so susceptible to disease. Red kafir, which is normally a week or more earlier than the Blackhull in the low plains, seems to become proportionally later as it is carried westward to higher elevations. At the Amarillo Experiment Farm it has been consistently later than the Blackhull for several years.

The group of kowliangs from North China and Manchuria contains some varieties (fig. 7) which are naturally very early, especially

among the brown-seeded sorts. Two or three (G. I. Nos. 171, 261, and 328) have matured in eighty to ninety days, thus proving earlier than the milos in the Panhandle of Texas. Some promising selections from them have been made in northern Colorado, in Nebraska, and in South Dakota. Coming, as they do, from latitude 40° or higher, they may prove able to germinate and grow at lower temperatures than the groups which have come from more southern latitudes.

EARLY CROPS AND EARLY SEASONAL RAINFALL.

The effect of earliness in permitting drought evasion is very important. Imagine two plants, one earlier than the other, but otherwise

FIG. 7.—Plat of selected Brown kowliang (G. I. No. 171)

similar in all respects. The earlier plant, having a shorter growing period, not only uses less water, but uses it earlier in the season. This is of especial importance in those parts of the semiarid country where much of the seasonal rainfall occurs in April, May, and June. The earlier plant might be able to mature its crop of seed on the summer rainfall. On the other hand, the later plant might be crippled at a critical stage by the exhaustion of the soil moisture during dry weather in August. It is fairly certain that in much of the Great

Plains region the greater part of the soil moisture in a field is not used by the growing crop, but is lost by evaporation, under the average tillage conditions.

Milos are earlier than kafirs, but are not known to be more truly drought resistant. At the experiment farm, Amarillo, Tex., under conditions of extreme drought from the middle of July until October, 1909, the milos yielded on the average 8.3 bushels and the kafirs only 5.5 bushels to the acre. In each crop the figures are the average of between 20 and 30 plats and show that the difference was really in the earliness of the milos as compared with the kafirs, the yields in normal years being about equal.

The writer has produced by selection a dwarf kafir (fig. 6) of the Blackhull variety which is nearly two weeks earlier than the ordinary strains. In 1908, a favorable season, it yielded less by 4.5 bushels than the average of the ordinary Blackhull varieties. In 1909 it yielded 14.4 bushels to the acre, while 20 ordinary strains averaged only 5 bushels, and the best of them yielded only 10.9 bushels. Part of the credit must probably be given to the dwarf stature because another selection, equally early but not dwarf, yielded only 10.7 bushels, as much, however, as any one of the later strains and twice as much as they averaged.

SELECTING FOR EARLINESS.

Earliness can be developed only by continuous selection. Such selections can be made either at heading time or at the time of ripening, but are preferably the results of records made at both periods. When the field or seed plat of the variety begins to head, a number of the earliest heads which are otherwise suitable for selection should be marked by means of tags on which is recorded the date of heading. When the heads on these selected stalks begin to show the characteristic colors and texture of the hard dough, or ripening stage, the date of ripening should be added to the tags. Other things being equal, those heads for which the shortest time has elapsed between heading and ripening are to be considered the earliest. These heads should be carefully saved separately and used for continuing the work another season.

In dry regions, where the amount of moisture in the soil is commonly the controlling factor in crop growth, the plants at the ends and sides of a field are often the first to produce heads, especially in dry seasons. This is because the outside plants have a larger area from which to draw moisture, or because run-off water often collects at the edges of fields and provides extra moisture. These early heads will be the first to ripen, but it does not follow that these plants are naturally earlier than the rest of the field.

DWARF STATURE.

For the grain-sorghum grower, a dwarf variety has two advantages over the taller strains. It requires less water and can be harvested with a grain header.

The larger the plant the more water it requires and the more it is likely to lose by transpiration. A small plant which can produce as much grain as a large plant will thus have a real advantage in a dry season. This is not true drought resistance, but merely a lower water requirement which permits drought evasion. The year 1909 was marked by severe drought during July, August, and September in the southern half of the Great Plains. At the Amarillo Experiment Farm, in Texas, 17 plats of milo gave an average yield of 6.8 bushels and 10 plats of dwarf milo an average yield of 11 bushels to the acre. The best plat of milo yielded at the rate of only 16.5 bushels, though in a low piece of ground, while the best dwarf milo yielded 23.2 bushels per acre. This advantage seems to be largely due to the smaller size of the plants of the dwarf variety and the consequent lower water requirement.

The development of an early dwarf strain of Blackhull kafir (fig. 6) has already been noted under the discussion of "Earliness" (p. 26). How much of its superiority was due to dwarfness and how much to earlier maturity can not be certainly known. Apparently about one-half was due to each cause.

The production of dwarf varieties has made possible the use of the grain header in harvesting the crop. Headers have been successfully raised on timbers until they will cut ordinary tall varieties, but this practice is not likely to become general. In case a successful row header is invented it is more likely to work well on low varieties than tall ones, especially in windy regions.

Selecting for dwarf stature raises the question of the ability of a plant to produce the same seed yields with a reduced stalk and leaf area. How far can reduction in the size and height of stems be carried without a reduction in the leaf area? How far can reduction of leaf area be carried without reducing grain production? These questions can not be answered except by long-continued investigations. It is much to be hoped that a series of careful and comprehensive experiments may some time accumulate data on the correlation of area of leaf surface and the power of seed production. The dwarf milo (fig. 8) and dwarf kafir are only 3 to 4 feet in height under conditions that make the normal crop 5 to 6 feet in height. The dwarf milos outyield the standard milos even in favorable seasons. The White durra, which is low, yields as much as the kafirs, which are of medium height or taller. The dwarf kafir seems likely

to hold its own in a series of years. An extra-dwarf Brown kowliang has been secured in China. It grows to a height of about 2 feet, but, like most newly introduced sorghums, does not show high yielding power.

These crops have originated in subtropical lands and are commonly inclined to large growth. While they have been used chiefly for grain production in their native homes, it has been by more or less primitive peoples, and the returns have not been large. Since coming to this country, most of the standard varieties have been reduced in

FIG. 8.—Plat of select Dwarf milo.

size and at the same time have increased in yielding power. The limit of profitable dwarfness has probably not been reached; it certainly has not been passed.

PRODUCTIVENESS.

OUTLINE OF THE PROBLEM.

The two keys to increased grain yields are better varieties and better methods of growing them. Better varieties means better filled and perhaps larger heads, erect and fully exserted from the boot, borne on stalks with fewer suckers and no branches. Better methods relate to proper and even spacing of stalks in the row and to thorough cultivation of the growing crop. They also include proper rotations and suitable tillage of the land when not in crop. Selections for better yields may naturally be continued as long as

the crop is grown. No one may say what returns will finally be obtained. It may reasonably be hoped, by continued effort, to double the present average yields.

Better Yielding Varieties.

METHODS OF SELECTION.

The origin of a better yielding variety need not be at an experiment station or other like source; it may be produced by the farmer himself from his own fields. In any event, the grower must continue the selection from year to year. In its simplest form this will mean the selecting

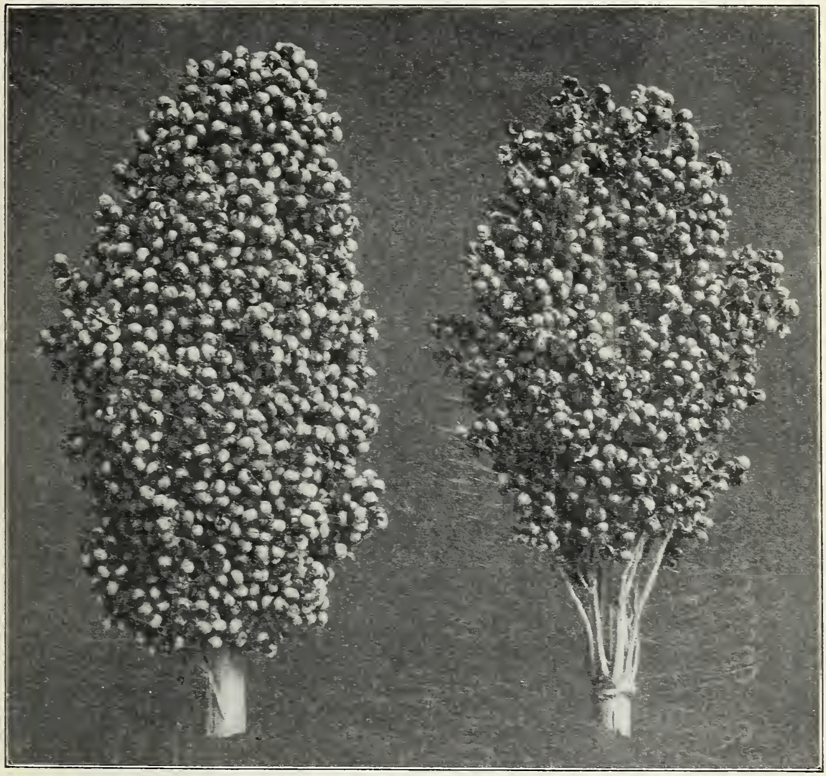

Fig. 9.—Two heads of milo, showing desirable and undesirable types.

of stalks of desirable size and habit, bearing large and well-shaped heads (figs. 9 and 10), well loaded with plump grains. This requires, of course, that the work of selection be done in the field. Selections made in the bin or crib would be without value in this regard. The work should be done before harvesting begins, and a sufficient quantity selected to furnish plenty of seed for the farm crop of the next year. Where the harvesting is done by hand and the seed selections

have not been previously made, the two operations can be combined, though not usually with complete satisfaction. A small box fastened to the near side of the wagon bed will serve to receive the selected heads. Where machine heading is practiced this method is, of course, not possible.

DESIRABLE FORMS OF HEADS.

Well-filled heads.—It is important that the heads be well filled at the butts and tips, as in high-grade corn ears. Less attention has been given to this matter than it deserves. Figure 9 shows desirable

FIG. 10.—Two plants of Blackhull kafir, 5½ feet high, selected for high yielding power.

and undesirable types in milo heads, and figure 10 shows desirable heads of Blackhull kafir. Milo may be taken as representing durras also, while the kafir may be regarded as the proper shape for kowliangs as well. The poorer head contains less grain and is therefore less productive. It also contains a larger proportion of fiber, and hence is less valuable as a feeding ration.

The heads selected should have shorter branches at the butt than in the rest of the head. These basal branches should be loaded with

seed down to the point where they join the rachis or central stalk of the head. Long basal branches are likely to droop and finally break away under the combined stress of weight and wind.

Fully exserted heads.—It is also important that the head be fully exserted from the boot, or upper leaf sheath. No seed is produced on the included portion, which often becomes moldy or rotten if wet weather prevails. Corn worms and false army worms (*Laphygma frugiperda*) breed in such places and add to the injury. When these heads with spoiled butts are piled with others they are likely to cause damage to the whole heap. Varieties in which the heads are not fully exserted are also more difficult to harvest by hand or machine.

The main agricultural difference between White kafir and Blackhull kafir is that the heads of White kafir never become fully exserted from the boot. White kafir was the first kafir variety to come into general cultivation in this country, but has since been almost wholly discarded, largely for this reason. Blackhull kafir, the present popular variety, bears the heads normally entirely free from the boot (fig. 10).

Large heads.—In selecting for large heads the proportionate size of the stalks must always be considered. Not the largest head alone, but the largest possible head on the smallest stalk is the most desirable selection. The grain sorghums are for use where limited rainfall is the principal controlling factor in grain production. Larger plants use and transpire more water than smaller ones. Selection should be made where the stand is uniform and fairly thick, and should include the largest and best heads produced under such conditions. They should not be made from the outer row of the field or plat, or from places where the stand is thin, even though the larger heads are found in such places.

Average weight of heads.—Close spacing of stalks in the row or an unfavorable growing season reduces the size of the heads, even if they are well filled. The average weight of heads also varies with the stand and seasonal conditions. Wide spacing and favorable conditions cause larger and heavier heads. Under average field conditions the heads of milo, Dwarf milo, and kowliang weigh from 3 to 4 ounces, and those of durra varieties about 3 ounces each. In the kafir group the heads are normally much heavier, weighing from 4 to 6 ounces.

PERCENTAGE OF GRAIN IN TOTAL PLANT.

It is unfortunate that during the years when these plants were new in this country no records were kept of the proportion, by weight, of seed to total plant. Such data covering a considerable period of years at the same point would show not only the progress made, but would be an index to what might be expected in the future. During

the past four years an attempt has been made to gather data on this subject. Even if the experiments had not been interrupted by drought, hail, and other environmental factors, four years is too short a period to yield conclusive data of this sort.

Table VI contains the average results obtained from a number of plats of several varieties. These results are not at all conclusive, but merely indicative of possibilities and are so offered. Of the four years considered, two have been favorable and two unfavorable crop years. The years 1906 and 1908, especially at the Amarillo Experiment Farm, were reasonably favorable seasons, as will be seen from the recorded yields. In 1908, however, the milo plats at Amarillo were almost wholly destroyed by hail, and must therefore be omitted. Their comparison with the Dwarf milo grown the same season would have been interesting. The years 1907 and 1909 were seasons of more or less drought by which the grain yields were usually reduced more than the vegetative growth. The figures for the four years are, therefore, not comparable.

TABLE VI.—*Percentage of grain in total weight of plants.*

Variety and number of plats averaged.	Grown on Texas farm at—	Year.	Row space per stalk.	Plants.	Grain.		
				Weight per acre.	Weight per acre.	Proportion in total plant.	Yield per acre.
			Inches.	*Pounds.*	*Pounds.*	*Per cent.*	*Bush.*
Milo:							
6	Amarillo	1907	8	5,375	1,434	26.5	24.7
3	...do	1907	4	5,274	868	15.6	15.0
7	Dalhart[a]	1908	10	3,854	1,462	37.9	25.2
1	...do	1908	30	3,150	830	26.3	14.3
3	Amarillo	1909	7	5,353	789	15.0	13.2
Dwarf milo:							
5	...do	1908	8	6,208	2,366	38.1	40.8
1	Dalhart[a]	1908	10	4,400	1,461	33.2	25.2
1	...do	1908	30	3,250	969	29.8	16.7
2	Amarillo	1909	8	3,807	1,007	25.7	18.3
Blackhull kafir:							
3	...do	1906	9	10,317	2,692	26.1	44.9
5	...do	1907	9	8,334	1,240	15.2	21.4
4	...do	1907	5	9,145	1,155	12.6	19.9
5	...do	1907	14	7,052	830	11.8	13.8
5	...do	1908	10	7,798	1,966	25.2	32.8
Brown kowliang:							
1	Dalhart[a]	1908	23	2,000	725	36.2	12.5
5	Amarillo	1909	5	3,546	934	26.6	16.1
Shallu:							
1	...do	1906	....	7,100	1,565	22.0	26.1

Another varying factor, which affects not only the yields but also the proportion of grain to plant, is the stand secured or the inches of row space afforded each stalk. In some of the experiments this factor was purposely varied, as in the two groups of milo and Blackhull kafir at Amarillo in 1907 and the milo and Dwarf milo at Dalhart in 1908. Unintentional variations occurred, caused by differences in the size and quality of the seed or in the nature or preparation of the

[a] In cooperation with the Office of Dry-Land Agriculture Investigations.

land. These produced nearly as great differences in the stand as were caused by the different rates of seeding. The average row space is shown in column 4. It may be noted that from 7 to 8 inches is considered the proper row space for milos and 9 to 10 inches for kafirs under Panhandle conditions.

The highest proportion of seed to plant was given by Dwarf milo at Amarillo and by milo at Dalhart in 1908. Two of the five plats of Dwarf milo at Amarillo, 1908, gave a proportion of over 40 per cent. As noted, the milos, which would have been comparable, were destroyed by hail. Of the seven plats of milo averaged at Dalhart, in 1908, three yielded higher than 40 per cent of grain, the highest being 47.2 per cent, which is probably the maximum yield for this crop.

Many other factors enter into the problem of increased productiveness. All the preceding discussion on earliness, drought resistance, and dwarf stature applies to this topic in some measure, as has been seen. However, the fact remains that no matter how great the performance of a plant under any given set of conditions it is possible to increase its producing power.

FREEDOM FROM SUCKERS AND BRANCHES.

Plant habits.—The habit of producing both suckers and branches is apparently characteristic of all sorghums, though in varying degrees. Suckers seem to be produced normally, but branches grow only under somewhat exceptional conditions. They will therefore be discussed separately.

Suckers.—Suckers are produced from the closely crowded lower nodes or joints of the stem just at the surface of the ground. In some plants suckers appear almost as early as the main stalk itself. In other cases they do not develop until the main stalk is well grown, or even after it has begun to mature its seed. Suckers may vary in number up to 10 or 15, according to the habit of the plant or to the particular environmental conditions, such as abundance of food and moisture. Though their heads are usually smaller, suckers differ from the main stalk chiefly in height and time of maturity. They are usually rather lower and almost always later in maturing, often very much so. Where the later part of a season is more favorable than the earlier, suckers often grow taller than the main stalk. Their difference in stature is objectionable only in harvesting, but their late ripening is a more serious matter.

The value of suckers in grain-sorghum crops is still a debated question. Many of the advertisements offering the seed of these crops dwell at length on their power to produce several stalks from one seed. Considering the cheapness of the seed of grain sorghums and the exceedingly small quantity (2 to 4 pounds) needed to plant an

acre, the grower can well afford to require only a single stalk from a single seed. In a forage crop, where abundance of leaves is wanted, suckers may be very desirable, but in a grain crop requiring little seed, the weight of evidence is against them. Their existence may be partly justified by their help in making a fuller crop where a thin stand occurs. This is largely offset by their somewhat later maturing. It is a question whether the seed produced really pays for the food and moisture used.

Selections should then be made with the object of entirely removing suckers. This can best be done by selecting seeds from stalks which produce none. If the crop on which selection is begun does not contain any stalks wholly without suckers, the selection should be made from stalks which have only a single sucker, or in which the suckers are very small and appeared very late in the season. In this way the tendency to produce them will gradually be overcome. Closer planting in the drills will also have this effect. The combined effect of these two methods will materially reduce the number of suckers.

Branches.—Unlike suckers, branches do not appear until the main stalk is headed out and usually not until it has nearly ripened its seed. In all sorghums the main head is borne on a long peduncle arising from the uppermost node. There is no lateral bud at this node; at all other nodes, however, there is borne a single lateral bud, lying in the slight furrow or concavity of the internode and fully protected by the tough, convolute leaf sheath arising from the node and completely enveloping the internode. Branches are most likely to be produced when the weather remains warm and there is abundant moisture late in the season. The bud at the internode below the one bearing the terminal peduncle begins to develop into a plant. It forces its way out, either at the ligular collar of the sheath or by splitting the dorsal surface of the sheath, and then rapidly elongates, putting out leaves and finally a terminal seed head. It thus becomes a miniature stalk, growing on the parent stalk and exactly like it in all respects except size. In the meantime the buds at the successively lower nodes have been making similar growth. If the season is long enough and the moisture sufficiently abundant all these developing buds will become fruit-bearing stalks. In extreme cases the lateral buds on the oldest or uppermost branches will themselves develop into branches. This compound branching could go on indefinitely if permitted by seasonal conditions.

The heads on these branches are much smaller and less productive than those on the main stalk. They are also much later in maturing. Advertisements which state that a single stalk produces 4 to 10 large heads are wholly misleading. The branches themselves, arising

first from the upper nodes, make the plant top-heavy and likely to lodge. The presence of branches interferes decidedly with the harvesting of the grain. When branching begins before the head on the main stalk is ripe its maturing is usually delayed. Branches use moisture that is often needed to be conserved for the next crop without making any adequate returns. These facts make the production of branches objectionable and they should be eliminated by selection and proper planting wherever they tend to occur.

Better Methods.

SCOPE OF TREATMENT.

Only methods of planting and the proper cultivation of the crop will be treated here. Rotations and general tillage to conserve moisture have their influence on crop improvement. In a new country, however, strict rotation systems can not be followed, and the general methods of dry farming can not be given in the limits of this paper. The principles are two: (1) Till so as to absorb the rainfall, (2) till so as to prevent evaporation. This subject has been fully treated elsewhere.[a]

PROPER STAND OR ROW SPACE.

The whole question of the proper stand or row space for the different varieties, under different conditions of soil and moisture, is one of which little is yet known. It is not the plant having the largest head which makes the heaviest acre yield, but the plant which can produce the largest head while growing in the smallest possible row space.

The results of four years' experiments at the Amarillo Experiment Farm, Texas, indicate that in general the kowliangs yield best with a stand of 1 stalk in each 5 or 6 inches of row; the milos and durras with 1 stalk in each 7 or 8 inches of row; and the kafirs with 1 stalk to each 9 or 10 inches of row. The rows are always 3½ feet apart and, as far as possible, the seeds are dropped singly in the rows (fig. 11). Under these conditions improved varieties in each of these three distinct groups give approximately the same yields. The Amarillo Experiment Farm has an elevation of 3,600 feet and an average annual rainfall of 22 inches, the larger part of which comes during the growing season. Further investigation, continuing the experiments through a longer period of years, may discover that better average yields will be produced at other spacings than those noted above.

---

[a] See Farmers' Bulletin 266, entitled "Management of Soils to Conserve Moisture," which will be sent free on application to the Secretary of Agriculture, Washington D. C., or to any Member of Congress.

It is probable that at other locations better results will be obtained at other rates of planting than those given for Amarillo. The rate will vary with different elevations, different amounts of annual rainfall, or a different proportion of it during the growing season, and with differences in the character of the soil.

DRILLS OR HILLS.

Another important question which has not yet been made the subject of experiment to any great extent is the comparative value of planting in drills and in hills. For instance, 1 stalk every 6 inches in the row, or 2 stalks in a hill every foot, or 3 stalks in hills 18 inches

FIG. 11.—Plat of Brown kowliang, showing stalks singly and evenly spaced in the row.

apart, or 4 stalks in a hill and the hills 2 feet apart, would all give the same number of stalks per acre. Would they give the same results in bushels of grain per acre? The answer is not known. All the evidence at hand indicates that the advantage is in favor of a single stalk in a place. Experiments with corn seem to show that where from 3 to 5 kernels are planted in a hill, results are better if the kernels are scattered a few inches apart instead of being dropped in a bunch.

Aside from the immediate question of yields, however, there are other reasons for preferring planting in drills rather than in hills. These reasons are connected with the production of suckers and pendent heads. Observation indicates that the fewest suckers and

pendent heads are produced where the stalks stand singly. Whether this be true or not, it is certain that where the stalks stand one in a place it is much easier to determine if suckers are produced and to take steps to get rid of them by selection.

PLANTER PLATES.

The difficulty of attaining proper rates of planting is partly psychological and partly mechanical. When the psychological objection is overcome the mechanical hindrance can easily be removed. The first sorghums extensively cultivated in this country were the sorgos, which are forage crops and as such are planted thickly. The other leading groups, the milos and kafirs, were also first regarded as forage plants and sown thickly. Corn planters were equipped with "cane" plates which dropped 10 to 25 seeds in a foot of drill. In this way the idea of thick seeding for sorghums became firmly fixed in the minds of growers.

The value of the milos, kafirs, and durras as grain producers was only gradually recognized. The necessity of planting thinly where high grain yields are desired was realized even more slowly. Though this necessity is now being seen by the great body of grain-sorghum growers, there is not yet knowledge and agreement as to the proper rates of planting. These vary with different conditions and must be made the subject of extensive experiments. In the meantime the manufacturers of planters, though recognizing the demand for different plates, have had little data on which to create a suitable supply.

So far as the size of the seeds is concerned probably only two sets of plates will be necessary in order to drop a single seed at a time of any variety. The two sets will have the holes of different sizes and perhaps of slightly different shapes also. Milos and durras have rather large seeds, more or less round in outline. Kafirs and kowliangs have smaller and oval seeds.

Having these two sets of plates, certain variations in the rate of planting will be necessary in order to space properly the seeds of different varieties in the drill. For instance, the seeds of kafirs and kowliangs will drop singly through the same hole, but the one should be planted 10 inches apart and the other only 5 inches. This variation in rate may be effected either by the adjustment on the planter which changes the speed of the plate or by using plates drilled with different numbers of holes. Where plates with the proper number of holes are not purchasable, blank plates can be bought and drilled by a blacksmith. Care should be taken that the holes are countersunk on the lower side of the plate so that seeds will not become wedged in them.

ADAPTABILITY TO MACHINE HANDLING.

GENERAL STATEMENT.

More than ever is it true that the demand is for crops which may be handled readily and profitably by machinery at every stage in their production. This has long been true of the small-grain crops. Corn and cotton are examples, however, of two great staple crops which must still be gathered by hand. The economic pressure is so great, however, that many and varied efforts are being made to produce machines which will gather the ears of corn and the fleecy staple of the cotton.

HEADERS.

If the grain sorghums are to become staple crops on a large scale they must be adapted to machine handling. In the early years of the cultivation of milo and kafir as important crops there were two methods of harvesting in vogue where seed was desired. The first was to cut the crop, stalk and all, with the corn binder and cure it in the shock. The heads were then cut from the bundles with a knife, saw, or hatchet. The second method was to cut the heads by hand in the field. This was done with a knife, and the heads were thrown into a wagon body, like ears of corn. Both these methods are in common use to-day.

A header designed for use in heading kafir was invented some years ago. Though still in use to some extent, this header has never been a popular or widely used machine. It is a rather heavy machine, not running upon its own gear, but attached to the side of the wagon box. It is heavy and hard to handle, destructive to the wagon bed, and not susceptible of quick and wide adjustments. Moreover, it heads but a single row at a time, and is rather expensive, considering all these points. It can not be used on milo because of the large percentage of pendent heads, nor on Dwarf milo because of its low growth. In recent years many attempts have been made to invent a satisfactory row header which would be free from the objectionable features mentioned. So far these have not been successful, though one of them gives considerable promise.

Since the introduction of Dwarf milo it has been found possible to harvest it rapidly and satisfactorily by means of the ordinary grain header. The standard milo and the kafirs are too tall for easy handling with this machine. A few ingenious farmers have, however, contrived to raise their headers on planks to a point where they will gather these taller crops with a fair degree of satisfaction. One great advantage of the grain header is that it enables the farmer to harvest his small grains and his feeding grains with the same machine. As

it cuts a number of rows at a time the work is done rapidly and a large area is easily harvested.

Two facts still prevent the general use of the grain header for these crops, namely, their height and the presence of pendent heads in some varieties. Here is a problem in selection for the farmer. Dwarf strains of kafir must be produced to equal the Dwarf milo already so popular. Varieties with erect heads must be had in all milos and durras.

PENDENT HEADS.

There are four great groups of grain-producing sorghums now under cultivation in this country. These are milo, durra, kafir, and kowliang. The first two groups originally had pendent heads (fig. 12). In the last two groups the heads are normally erect. The durras are but little grown because of the wasteful shattering of the seed, the irritating hairs on the glumes, and the pendent heads. A strain of White durra has been perfected in which 100 per cent of the heads are erect under all conditions. Improvement in the milos has not progressed so far. The percentage of erect heads varies from 50 to 95, depending, perhaps, more upon the season than on the particular strain. The character of pendent heads does not yield readily to selection. It doubtless can be entirely eliminated, however, by long-continued selections.

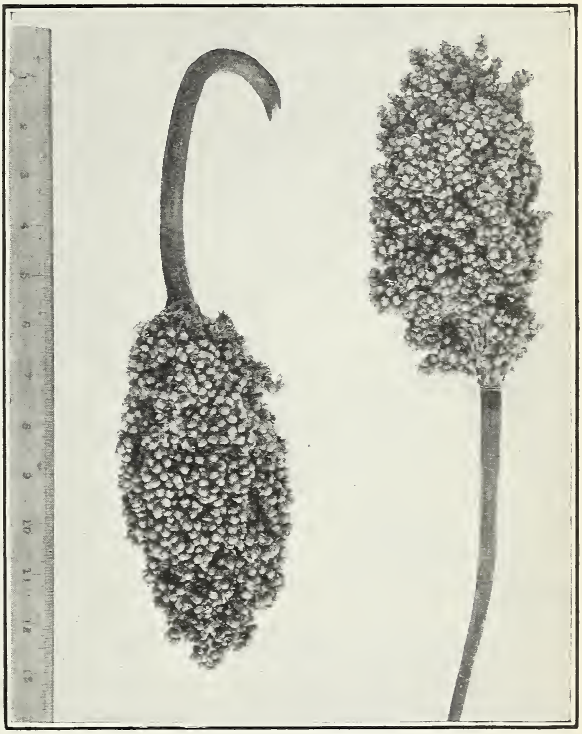

Fig. 12.—Milo heads; one pendent, one erect.

The tendency of the head to hang downward on a recurved peduncle is an inherent one. Because the largest heads are most likely to be

pendent it has been held that the bending was caused by the weight of the head. This is apparently not true. The character, while inherent, finds expression most often in vigorous stalks. The same vigor of growth that produces a large head tends to produce also a pendent head. This increases the difficulty of solving the problem by selection. Other things being equal, vigorous plants producing large heads are desirable. If erect heads are normally found in the fields only on weaker and less vigorous stalks their continued selection might produce a weak and unprofitable variety. This fact has made progress toward perfect erectness much slower than it otherwise would have been.

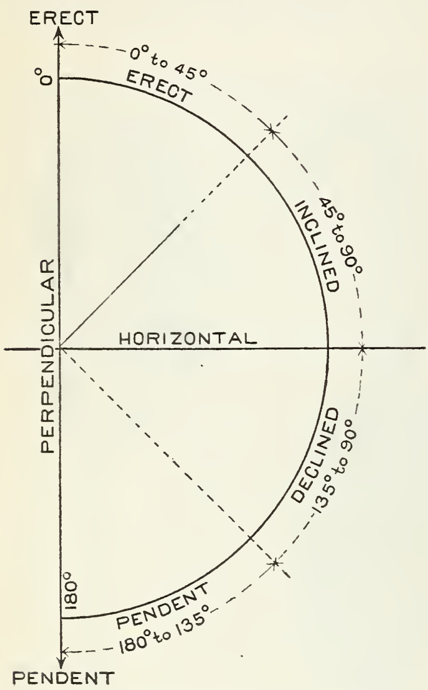

Fig. 13.—Diagram showing the named positions of heads of milo or durra.

The experiments show that the planting of these crops rather thickly in drills tends to prevent too great a vigor of growth and therefore checks the production of pendent heads without decreasing the yield. With the same number of plants per acre those planted in hills appear to produce more pendent heads than those spaced evenly in drills.

The diagram shown in figure 13 is tentatively suggested as an aid to those who are recording results in breeding these crops. The half circle through which the head may pass in shifting from the absolutely erect to the absolutely pendent position is divided in this diagram into four sectors of 45° each. The head is called erect when not inclined more than 45° from the perpendicular, because it is erect for all practical purposes of harvesting. Between 45° and the horizontal it is called inclined, and in the first 45° below the horizontal it is called declined, while below that it is called pendent. Though all such heads are not really pendent, the header must be set about as low in order to harvest them as if they were hanging straight down.

SUMMARY.

The grain-sorghum belt, broadly speaking, is the southern half of the Great Plains region, nearly 400 miles wide and 1,000 miles long. It is characterized by low rainfall and high evaporation, by varied soils and considerable elevation, with correspondingly shortened seasons. It is fitted to become a noted stock-feeding region.

The grain sorghums, including milos, durras, kafirs, and kowliangs, are of recent introduction and have become important only within the last twenty years. By their earliness, drought resistance, and adaptability they are especially fitted for growth under Great Plains conditions.

The grain is largely used for feeding stock on the farms where grown. Its feeding value is nearly equal to that of corn. The protein content averages higher than that of corn, the fat and fiber content lower. Any surplus is readily marketed as whole grain or as chops for feeding purposes. It is in much demand for poultry food, for which it is admirably suited. Over 25 per cent of the ingredients of prepared poultry foods in the eastern United States is kafir grain.

It seems probable that the meal can be used as readily as corn meal for human food and that both the meal and flour can be used in mixtures with wheat flour.

Kansas and Oklahoma grow annually over 1,250,000 acres. It is probable that an equal area is also grown in Texas. The grain-sorghum acreage in Kansas is nearly 10 per cent of the corn acreage, and in Oklahoma over 12 per cent. More than half the kafir and over 95 per cent of the milo are grown on the dry lands west of the ninety-eighth meridian. In this region the proportionate acreage of grain sorghums to corn is steadily increasing.

In spite of the less favorable conditions under which much of the crop is grown the average acre value of the grain sorghums in Kansas is higher than that of corn, and in Oklahoma it is 70 per cent as great.

The grain sorghums may be greatly improved through the selection of better varieties and the use of better methods. Improvement will be chiefly in the direction of (1) drought resistance, (2) earliness, (3) dwarf stature, (4) productiveness, (5) freedom from suckers and branches, and (6) erect heads.

The drought resistance of the grain sorghums is very important. It is probably a combination of several characters, some actually drought resistant, as controlled transpiration and a strong root system, others only drought evasive, as earliness and dwarfness.

Improvement in earliness is necessary in adapting the crop to regions having a short growing season. Early plants take advantage

of early seasonal rainfall and also have lower water requirements. Milos, White durra, and some Brown kowliangs are normally early. An early dwarf strain of Blackhull kafir has been produced. Dwarf stature lowers the water requirement of the crop and permits heading by machinery.

Better yielding varieties may be produced by selecting for well-shaped, well-filled heads, fully exserted from the boot, and as large as possible in proportion to the size of the stalk.

The value of suckers in the grain-sorghum crops is doubtful. They are often shorter and usually later in maturing. Seed is so cheap and so little is used per acre that only a single stalk from each seed need be required. Branches should be eliminated, because their objectionable features render them utterly worthless for grain production.

Experiments show that under Panhandle conditions kowliangs give best yields with a stand of 1 stalk to each 5 or 6 inches of $3\frac{1}{2}$-foot rows; milos and durras each 7 or 8 inches, and kafirs each 10 inches. Under different conditions the spacing will need to be varied somewhat.

Better results are probably secured from plants single in the drill than from the same number of plants in hills. Single stalks are also more easily selected and harvested and seem to produce fewer suckers. To plant single seeds of the different grain sorghums two sets of plates are needed, with holes of different sizes; one set for milos and durras and one for kafirs and kowliangs. To space different varieties properly in the drill, speed adjustments on the planter or plates with different numbers of holes will suffice.

The ordinary grain header harvests low varieties like dwarf milo with complete success. The invention of satisfactory row headers or the creation of other dwarf varieties will finally solve the harvesting problem.

Pendent heads are usual in some varieties. They can be slowly eliminated by selection and proper planting.

INDEX.

203

○